Hand function in Low risk preterm infants: The relation with muscle power regulation

Plantinga, Y.; Perdok, J.; Groot-Buskop, L.M.

published in
Developmental Medicine and Child Neurology
1997

DOI (link to publisher)
10.1111/j.1469-8749.1997.tb08197.x

document version
Publisher's PDF, also known as Version of record

Hand function in low-risk preterm infants: its relation to muscle power regulation

Yvonne Plantinga
Jeannette Perdock
Laila de Groot

Some preterm infants show a discrepancy in muscle power often recognisable as hyperextension of trunk and shoulders. Even if there is no evident pathology involved, the hyperextension influences later hand function. In this study we assessed a group of healthy infants (N=51) at the age of 39 weeks: 32 were born preterm (and corrected for gestational age) and 19 were born at term. Both quantitative and qualitative measures of hand function were obtained. It was found that the preterm infants scored significantly lower scores in both assessments for hand function. Moreover, a significant correlation was found between the quality of hand function at the age of 39 weeks and hyperextension of the trunk at 18 weeks. Hyperextension of the trunk at 18 weeks had a high predictive value for poor hand function at 39 weeks and thus should hold implications for clinical and therapeutic management.

Well-coordinated hand function depends to a large extent on postural control (Illingworth 1980; Von Hofsten 1989, 1993; Bilo and Voorhoeve 1990; Smits-Engelsman and Portier 1991). Infants born preterm often have problems with acquiring this control. One of the factors influencing postural control stems from adequate muscle power regulation of the trunk. In some preterm infants, muscle activity seems to be exaggerated and is often recognisable as hyperextension of trunk and shoulders (Georgieff et al. 1986; Georgieff and Bernbaum, 1986; Gorga et al. 1988; de Groot et al. 1992 a, b, 1993). When this hyperextension lasts beyond the corrected age of 12 weeks or is accompanied by other neurological signs it should be considered an alarm signal and further development should be closely monitored (Touwen and Hadders-Algra 1983).

The origin of the hyperextension of the trunk in preterm infants may reside in the positioning to which they are necessarily subjected after birth. Maintenance of a predominantly supine posture before term may influence the differentiation of muscle fibres and thereby the myogenic and neurogenic development of the infant. The phenomenon of trunk hyperextension has been regarded in previous literature as being of no consequence for later development and of being transient. But it clearly affects the stability of the trunk and thereby motility as a whole. In our earlier studies, hyperextension was found to be still observable in functions such as rotation round the body axis in sitting, and in hampering unsupported sitting at the age of 39 weeks corrected age (de Groot et al. 1995). When early walking was assessed in the same group of infants, the discrepancy in muscle power regulation could still be seen as coordination problems in the sequence of flexor–extensor activity in functions such as picking up a toy from the floor (de Groot et al. forthcoming).

Gorga et al. (1985) pointed out that at the age of 9 months, infants born at term have better upper-extremity control than preterm infants. For instance, fewer preterm infants show a pincer grasp compared with term infants at that age. They found a significant difference in the quality of gross movement patterns in the first year of life between preterm and term infants. They pointed out the necessity for adequate muscle power, but did not identify the problems found. In their study only motor milestones were assessed. Forslund and Bjerre (1985) found significant differences in fine motor functions between term and preterm infants, but they did not correct the latter for gestational age. Research done by Piper et al. (1989) revealed significant differences in fine motor functions between preterm and term infants at the corrected ages of 8 and 12 months. However neither of them mentioned a detailed qualitative scale or tried to find an explanation for this phenomenon. Konishi and Prechtl (1994) studied hand and finger movements in detail in preterm infants with and without brain damage at term age. They could not detect any significant differences between the two groups and concluded that this method of early observation was not useful as a diagnostic tool. However, it seems likely that the influence of poorly regulated muscle power is not detectable at this early age and the eventual consequences for later function are better observed only when postural control against gravity starts to play a role (de Groot 1993).

In this study a hypothesis is generated: the observed disregulation of muscle power at 18 weeks, described as hyperextension of the trunk, is of a more global character and that this phenomenon has consequences for later development and can be observed when the infant is older in functions such as the manipulation of objects.

To test the hypothesis we studied hand function in detail at 39 weeks' corrected age in a standardised free field situation, and correlated these data with outcomes of hyperextension of the trunk found in the same infants at the earlier corrected age of 18 weeks.

Method

SUBJECTS

Our study group consisted of 51 carefully selected white infants: 32 low-risk preterm and 19 term infants. Their gestational ages ranged from 27 to 34 weeks for the preterm and from 38 to 40 weeks for the term group. There was one missing value at the 18-week examination.

The preterm population was recruited from the intensive care unit of the Academic Hospital of the Vrije Universiteit and other regional hospitals near Amsterdam during the period January 1989 to January 1993. Birthweight was between the 10th and 75th centiles according to growth curves for the Dutch population (Kloosterman 1970). The preterm group was selected to be at low risk for later developmental problems. The term infants were recruited from hospitals and maternity wards in the region.

No infant had any evidence of hypoglycaemia and infants were not recruited if they had severe periventricular haemorrhage (Papile grade 3 or 4) or evidence of periventricular leukomalacia. Infants were only selected if they showed no karytopic abnormality, fetal infection, or malformation. All were singletons. The mothers were all aged between 18 and 40 and were at least 1.60m tall. Their recorded alcohol consumption was less than three units per day. The dating of the pregnancy was based upon reliable maternal information and if doubtful confirmed with an early ultrasound scan.

All preterm infants were examined at 35 weeks postmenstrual age and at their expected date of delivery. The assessment of the term infants started at birth or within a week of it. Infants were only entered into the study if they had a normal neurological assessment with no evidence of asphyxia or other serious brain abnormalities. The neonatal status of the infants is given in Table I.

PROCEDURE

The infants were assessed at 18 and 39 weeks' corrected age under standardised conditions in a research room at the Faculty of Human Movement Sciences. All assessments were completed one hour before the next feed with the infant undressed and in an active state (not drowsy nor crying). The research room had an even temperature of 28° C with humidity about 30%. Lighting was diffuse and there were no unusual stimuli. The examinations of the infants took place in a standardized clinical setting and were conducted by one experienced examiner (LdG) who was unaware of the infants' perinatal history. Hand function was assessed while the infant was sitting freely on the mother's lap not leaning against the mother, but stabilized by the mother at the pelvis. The infant was offered several coloured flat teething rings and several beads. The rings and beads were offered to the infant at a mid line, so that hand preference was not biased. Assessments were based upon normal hand function at the age of 39 weeks (Illingworth 1980, Bilo and Voorhoeve 1990) and consisted of quantitative and qualitative items.

Teething rings were used to trigger the scissor grasp, unimanual and bimanual grasping, and the transfer of the ring from one hand to the other. During the performance of these functions the ability to pronate and supinate the underarm were also recorded. The beads were used to elicit functions such as pincer grasp and index-finger pointing. The items are listed in Table II and were scored on a two-point scale: behav-

Table I: Neonatal status of subjects

Infants	*N*	*Mean (SD) gestational age (wks)*	*Mean (SD) birthweight (g)*
Term	19	40 (1)	3526 (291)
Preterm	32	32 (2)	1598 (418)

Table II: Assessment for quantitative hand function

Test items
Scissor grasp
Pincer grasp
Index finger pointing
Transfer an object from one hand to the other
One object in each hand
Voluntary pro- and supination
Voluntary wrist movements
Unimanual grasping

Table III: Assessment for qualitative hand function

Test items
Muscle power regulation of the arm when:
grasping rings
grasping beads
Muscle power regulation of the hand when:
grasping rings
grasping beads
transferring an object from one hand to the other
Coordination when:
grasping rings
grasping beads
transferring an object from one hand to the other
Associated movements when:
grasping beads
Synergic movements when:
grasping rings
grasping beads
voluntary pro- and supination
voluntary wrist movements
Support when:
grasping rings
grasping beads

iour considered optimal for age and behaviour not considered optimal for age.

All assessments at the corrected age of 39 weeks were videotaped with emphasis on the hand function and retrospectively evaluated by two independent observers, who were unaware of the perinatal history of the infants. An interrater reliability test resulted in an agreement of 98% (κ 0.98).

In addition to the quantitative observations, qualitative aspects of hand function were studied. For this assessment, tone regulation of the arm and hand, coordination, associated movements, synergic movements, and support when grasping were measured (see Table III).

The qualitative items were scored on a three-point scale (0, 1, 2) with 0 being the optimal score, 1 being borderline and 2 being non-optimal.

The muscle power regulation of the arm was judged to be optimal when the infant's arm moved straight to the target and did not dash past the object (score 0). Performance was judged as borderline when the infant grasped the object but in a clumsy, awkward way (score 1). The item was judged as non-optimal when the infant made an obvious detour before grasping the object and/or missed it (score 2).

The muscle power regulation of the hand concerned the balance between extensor and flexor muscles of the hand in anticipation of grasping the object. The performance was judged to be optimal when the muscle power of flexors and extensors were in balance for a smooth performance (score 0). The function was judged to be borderline when the flexion-extension was not properly adjusted and the anticipatory movement was awkward (score 1). A non-optimal score was decided upon when clearly exaggerated extension was observed (score 2).

Coordination was judged as being optimal when the infant executed the movement fluently and elegantly (score 0). The item was judged to be borderline when the infant moved with less fluency and smoothness (score 1). The item was considered to be non-optimal when the movements were cramped, were clearly not fluent, and the temporal sequence was not adequately matched to the movement (score 2).

Associated movements were judged to be optimal when during the grasping there were no detectable associated movements on the contralateral side (score 0). The item was considered non-optimal when there were definite associated movements on the contralateral side (score 2). Otherwise the item was considered to be borderline (score 1).

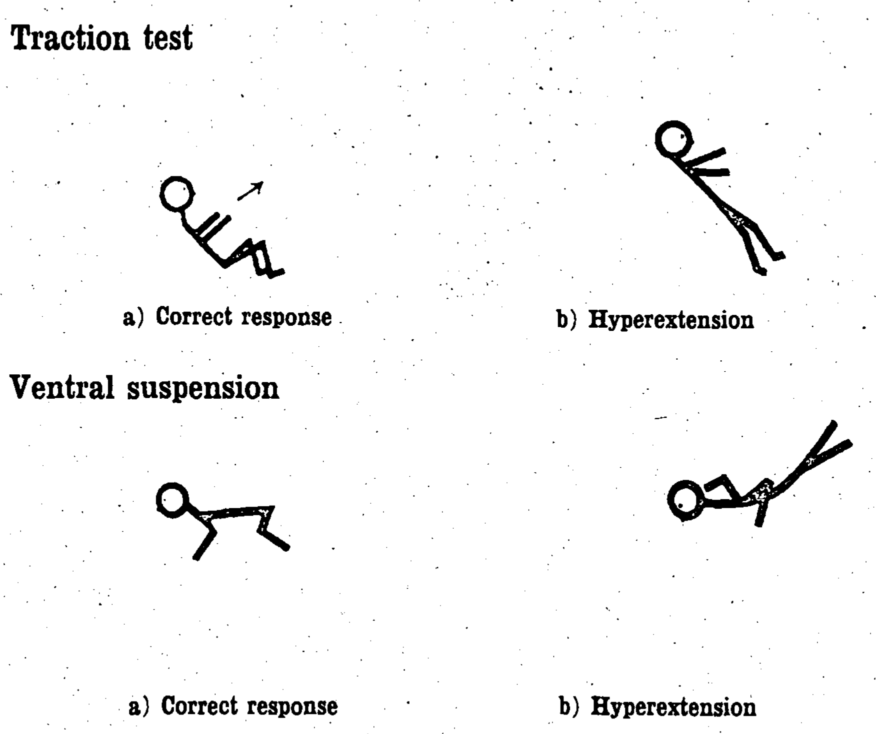
Synergic movements were judged as optimal when the interlimb joints (i.e. shoulder, elbow, or wrist) could be moved indepently from one another (score 0). The item was judged to be non-optimal when the joints in the arm clearly moved in a synergic way (score 2). When doubtful the item was judged borderline (score 1).

Support when grasping was judged optimal when the infant did not need any support for the arm or hand which was grasping (score 0). The item was considered borderline when the infant needed to support its hand on the hand of the examiner (score 1). The item was judged to be non-optimal when the infant was seeking support by fixing the proximal joints for both arm and hand on mother's or the examiner's arm (score 2).

For statistical analysis the 1 and 2 scores were added and this amounted to an optimal or non-optimal outcome for all qualitative hand functions measured.

The internal consistency of the instruments were validated for each area of the assessment and resulted in a Cronbach alpha of 0.69 for the quantitative scale and 0.78 for the qualitative scale. The scores of the items of each scale were then added. Cut-off scores of both scales were established and were based on the data of the term group. Cut-off scores were used to categorise the infants as showing optimal, borderline or non-optimal performance. For the quantitative assessment, infants were considered to have an optimal performance when they scored optimal on between five and eight items, borderline when only three to four optimal items were achieved and non-optimal when they had less than three optimal performances. The qualitative items were scored as follows: the infant was considered to be in the optimal range when optimal

Figure 1: *Examples of trunk hyperextension in preterm infants*



scores were obtained on between 10 and 15 items; borderline when they attained an optimal score on five to nine items and less than five optimal scores was considered as non-optimal.

The hyperextension data at 18 weeks' corrected age were derived from earlier studies of the same infants (de Groot et al. 1992a, b; 1993) and were based on relevant items and outcomes of the age adequate neurological assessment (Touwen 1976). The amount of the active muscle power in the trunk was assessed in several positions and compared with items measuring basic passive tone. A discrepancy between the two components of muscle power was found in many preterm infants and is clinically observable as the hyperextension of the trunk. Examples are given in Figure 1.

To investigate the relationship between hyperextension of the trunk at the corrected age of 18 weeks and hand function at the corrected age of 39 weeks of the same infants, indices of efficacy were calculated.

STATISTICAL ANALYSIS

The Mann–Whitney U test was used to compare groups. The Spearman Correlation test was used to determine the relation of hand function to the hyperextension as measured at 18 weeks corrected age. The hyperextension was scored on a three-point scale (de Groot 1993). To calculate the indices of efficacy, the borderline and non-optimal scores of the hyperextension were added to produce a dual score.

Results

The outcomes of the hyperextension of the trunk at 18 weeks' corrected age are given in Table IV.

Table IV: Follow-up clinical examination findings for recurrence and non-recurrence groups

	Preterm	*Term*
No hyperextension (optimal score)	6	13
Slight hyperextension (borderline score)	12	5
Hyperextension (non-optimal score)	13	1
Total	31	19

QUANTITATIVE HAND FUNCTION

Of 19 term infants, 16 obtained optimal overall scores and three were categorised as having a borderline score. There were no term infants in the non-optimal range. Of 32 preterm infants, only 13 received an optimal, 12 a borderline and seven a non-optimal score. The results and outcomes are given in Figure 2.

The preterm population scored significantly less well at quantitative hand function (Mann–Whitney U test, P=0.001). The preterm population scored significantly less well on palmar grasp, pincer grasp, voluntary pro- and supination and on voluntary wrist movements.

QUALITATIVE HAND FUNCTION

Fifteen term infants had an optimal outcome and four were considered borderline on the qualitative assessment. Ten preterm infants scored optimal, 14 borderline and eight non-optimal on the same criteria. The results are given in Figure 2.

The preterm group showed significantly poorer qualitative hand functions (Mann–Whitney U test, P=0.001). The specific items the preterm infants scored lower on were: muscle power regulation of the arm; muscle power regulation of the hand; coordination and synergic movements when grasping the rings and beads; associated movements when grasping the rings; and support when grasping the beads.

CORRELATION WITH HYPEREXTENSION

The quantitative and qualitative scales of hand function in the preterm infants were correlated with hyperextension of the trunk of the same infants at the corrected age of 18 weeks.

No significant correlation was found between the quantitative hand function and hyperextension of the trunk, but a significant correlation was found between the qualitative hand function at the corrected age of 39 weeks and the hyperextension of the trunk at the age of 18 weeks' corrected age (Spearman r=0.36; P=0.02; N=31).

The indices of efficacy were calculated and showed a good sensitivity and predictive value of hyperextension of the trunk for a poor quality of hand function (see Table V).

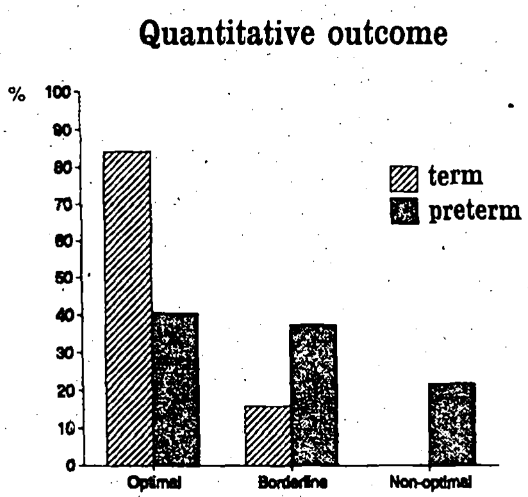


Figure 2: *Results of quantitative hand function tests.*

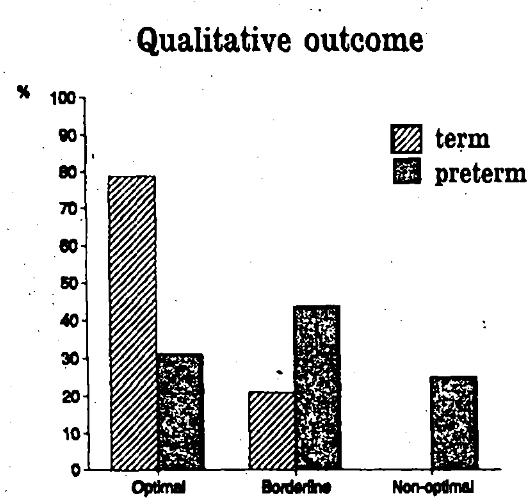


Figure 3: *Results of qualitative hand function tests.*

Discussion

Significant differences were found in quantitative and qualitative hand function between preterm and term infants. On both aspects of hand function preterm infants performed less well. The quantitative items of the assessment are assumed to be based on maturational aspects of development. Preterm infants are known to reach milestones later. Corrected gestational age was used in our population, but we still found significant differences in hand function between preterm and term infants.

Sensitivity was high: 19 of the preterm infants who showed poor qualitative hand function at the corrected age of 39 weeks also displayed hyperextension of the trunk at the corrected age of 18 weeks. However, specificity was low: only 3 of the preterm infants who had optimal scores for hand function at the corrected age of 39 weeks, did not show hyperextension of the trunk at the corrected age of 18 weeks. When predictive values were taken into account, the positive predictive value was particularly high: few infants who had shown hyperextension of the trunk developed good qualitative hand function. From the negative predictive value it is evident that 50% of the infants who did not show hyperextension of the trunk at 18 weeks corrected age still developed poor hand function, indicating that there must be additional significant factors.

The accomplishment of postural control is considered a prerequisite for performing well-coordinated movements of the arm and hand (Illingworth 1980, Von Hofsten 1989, Bilo and Voorhoeve 1990, Smits-Engelsman and Portier 1991, Von Hofsten 1993) and it is known that preterm infants have problems with their postural control due to a discrepancy in the flexor and extensor muscle power of the trunk (Gorga et al. 1985; Georgieff et al. 1986; Georgieff and Bernbaum. 1986; Gorga et al. 1988; de Groot et al. 1992a, b; 1993; 1995). The discrepancy in muscle power not only hampers the establishment of a stable posture but also seems to have consequences for other functions. It seems plausible that such discrepancies are of a more global character and have consequences also for hand function. In the items used for the qualitative assessment in our study, i.e. muscle power regulation, associated movements and coordinated movements, the regulation of muscle power is an important factor for fluent function. A refined tuning of flexor and extensor muscles is needed for the optimal handling of objects.

The discordant relationship in muscle power may arise from the low passive tone that preterm infants display after birth. The preterm infant spends a long time on its back. Consequently the back muscles are in almost continuous contact with the supporting surface, and this situation may then

Table V: Correlation between hypertension of the trunk at 18 weeks' corrected age.

Hyperextension of the trunk	*Qualitative hand function* Non-optimal	Optimal	*Total*
Present	19	6	25
Absent	3	3	6
Total	22	9	31

preferentially activate the stretch receptors of the erector muscles of the trunk, which in turn favours extensor over flexor muscles. Animal research shows that fixation as well as abnormal stimulation can disrupt the normal muscle fibre differentiation (Williams et al. 1986, Jansen and Fladby 1990).

While such a discrepancy between the two components of muscle power may be a transient phenomenon exacerbated by environmental circumstances, it seems to have lasting neurogenic consequences by influencing the alpha–gamma linkage at a critical stage during development and to have longer-lasting global consequences for the development and coordination of movement. Variability in the alpha–gamma coactivation is needed to adjust to the changing environmental conditions during voluntary movements such as reaching and grasping. Konishi and Prechtl (1994) found no differences in finger movements at term age between preterm infants with and without brain damage. At this age finger movements serve a more social, contact purpose and do not yet need the precise spatial control of differentiated finger movements which are necessary for manipulation. This finer tuning of more voluntary movement will not occur until motor-cortex neural connections are developed. In the Rhesus monkey these connections reach an adult level at around 8 months of age (Kuypers 1982). Thus discrepancies in the regulation of muscle power seen in voluntary functions such as reaching and grasping cannot be observed before this period.

Thelen (1990) mentioned that to establish adaptive actions, multimodel perception of the task is needed which, together with the body dynamics, play an important role in the skill of reaching and grasping. For example, the anticipatory adaptive hand shaping is acquired by practice with handling objects. If, through a discrepancy in muscle power, coordination of agonist and antagonist becomes difficult to achieve, the development of hand function will be retarded and abnormal. Ruff et al. (1984) state that this kind of manipulation contributes directly to an infant's cognitive development, and thus the discrepancy in muscle power in the first year of life can indirectly bring about learning and behaviour problems later. When the problems in hand function in these infants persist, they may have writing problems as children. For skilled writing good co-ordination between agonist and antagonist is necessary as well as the absence of synergic movements in the arms and body (Smits-Engelsman and Portier 1991).

The present findings are pertinent in that hyperextension of the trunk in preterm infants in the critical period around 18 weeks causes problems with exploration and manipulation of objects. This gives the infant less opportunity to learn about the properties of objects and thus hampers the fine tuning of muscles which, in turn, results in a lack of the coordination needed for optimal hand function.

In conclusion, in our study we found that hand function even of low-risk preterm infants is less advanced and different in quality compared with hand function in term infants. The way hand function developed in our preterm population should not be seen as a sign of definite major pathology. It is not clear whether this dysfunction will be transient or permanent and if and how it will influence later development.

Thus future studies should take two directions: firstly, the development of the hand function of the same children at later ages should be examined and secondly, the effect of early intervention aimed at preventing hyperextension of the trunk muscles should be considered. This intervention should start in the neonatal care unit by preventing hyperextended postures and by adjusting nursing procedures emphasizing the handling of the infant in a more flexed position.

Accepted for publication 13th February 1996.

Authors' Appointments
Yvonne Plantinga, MA Movement Sciences, PT.
Jeannette Perdock, MA Movement Sciences, PT; 'Meliomare' Rehabilitation Centre.
*Laila de Groot, PhD Movement Sciences, Pediatric PT, Associate Professor, Faculty of Human Movement Sciences, Vrije Universiteit, Amsterdam, The Netherlands.

**Correspondence to third author at* Vrije Universiteit, Faculty of Human Movement Sciences, vd Boecorststraat 9, room D-639, 1081 BT Amsterdam, The Netherlands.

References

Bilo RAC, Voorhoeve, HWA. (1990) *Kind in ontwikkeling.* Lochem: De Tijdstroom.
Forslund M, Bjerre I. (1985) Growth and development in preterm infants during the first 18 months. *Early Human Development* **10:** 201–16.
Georgieff MK, Bernbaum JC, Hoffman-Williamson M, Daft A. (1986) Abnormal truncal tone as a useful early marker for developmental delay in low birth weight infants. *Pediatrics* **77:** 659–63.
Georgieff MK, Bernbaum JC. (1986) Abnormal shoulder girdle tone in premature infants during their first 18 months of life. *Pediatrics* **77:** 664–9.
Gorga D, Stern FM, Ross G. (1985) Trends in neuromotor behavior of preterm and fullterm in the first year of life: a preliminary report *Developmental Medicine and Child Neurology* **27:** 256–66.
Gorga D, Stern FM, Ross G, Nagler W. (1988) Neuromotor development of preterm and fullterm infants. *Early Human Development* **18:** 137–49.
de Groot L, van der Hoek A, Hopkins B, Touwen BCL. (1992*a*) A method to assess the development of muscle power in preterms after term age. *Neuropediatrics* **23:** 172–9.
— — — — (1992*a*) Development of the relationship between active and passive muscle power in preterm infants after term age. *Neuropediatrics* **23:** 298–305.
— — — — (1993) Development of muscle power in preterm infants: individual trajectories after term age. *Neuropediatrics* **24:** 68–74.
— (1993) *Posture and Motility in Preterm Infants.* Amsterdam: VU University Press.
— Hopkins B, Touwen B. (1995) Muscle power, sitting unsupported and trunk rotation in pre-term infants. *Early Human Development* **43:** 37–46.
— de Groot CJ, Hopkins B (1996) An instrument to measure independent walking: are there differences between preterm and fullterm infants? *Journal of Child Neurology.* (Forthcoming)
von Hofsten C. (1989) The organization of arm and hand movements in the neonate. In: von Eyler, C. editor. *The Neurobiology of Early Infant Behaviour.* London: Macmillan.
von Hofsten C. (1993) Prospective control: a basic aspect of action development. *Human Development* **36:** 253–70.
Illingworth RS. (1980) *The Development of the Infant and Young Child.* Edinburgh: Churchill Livingstone.
Jansen JKS, Fladby T. (1990) The perinatal reorganization of the innervation of skeletal muscle in mammals. *Progress in Neurobiology* **34:** 39–90.
Kloosterman GJ. (1970) On intrauterine growth. *International Journal of Gynaecology and Obstetrics* **8:** 895–912.
Konishi Y, Prechtl HFR. (1994) Finger movements and finger postures in pre-term infants are not a good indicator of brain damage. *Early Human Development* **36:** 89–100.
Kuypers HGJM. (1982) A new look at the organisation of the motor system. In: Kuypers HGJM, Martin GF editors. *Progress in Brain Research. Vol 57. Descending Pathways to the Spinal Cord.* Amsterdam: Elsevier Biomedical. p 381–97.
Piper MC, Byrne PJ, Darrah J, Watt MJ. (1989) Gross and fine motor development of preterm infants at eight and 12 months of age. *Developmental Medicine and Child Neurology* **31:** 591–7.
Ruff H, McCarton C, Kurtzberg D, Vaugham HG. (1984) Preterm infants' manipulative exploration of objects. *Child Development* **55:** 1166–73.
Smits-Engelsman BCM, Portier SJ. (1991) Motoriek en schrijven, deel 1: Motorische ontwikkeling en schrijfproblemen. *Nederlands tijdschrift voor fysiotherapie* **101:** 235–41.
Thelen E. (1990) Coupling perception and action in the development of skill: a dynamic approach. In: Bloch H, Bertenthal BI, editors. *Sensory-Motor Organizations and Development in Infancy and Early Childhood.* Dordrecht/Boston/London: Kluwer Academic Publishers. p 39–56.
Touwen, BCL. (1976) *Neurological development in infancy. Clinics in Developmental Medicine No. 58.* London: SIMP with Heinemann.
Touwen, BCL, Hadders-Algra M. (1983) Hyperextension of neck and trunk and shoulderretraction in infancy – a prognostic study. *Neuropediatrics* **14:** 202–5.
Williams P, Watt P, Bicik V, Goldspink G. (1986) Effect of stretch combined with electrical stimulation on the type of sarcomeres produced at the ends of muscle fibres. *Experimental Neurology* **93:** 500–9.